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NEXT-GENERATION LONG-RANGE STRIKE:
COMBATING THE TYRANNY OF DISTANCE

by

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Biography

Colonel Christopher J. Brunner is a Master Navigator with over 3300 total flying hours, primarily in the B-1. He is a 1998 graduate of the US Air Force Weapon School. After serving as a Weapons School instructor from 1999 – 2002, Colonel Brunner was assigned to the Air Staff where he served as the B-1 program element monitor and chief of the global persistent attack capabilities branch overseeing requirements development for the A-10, B-1, F-16, and F-35. While assigned to the Air Staff, Colonel Brunner authored the CORONA approved long-range strike flight plan. In 2005, Colonel Brunner returned to the B-1 as Commander of the 337th Test and Evaluation Squadron. During this time, he was responsible for testing and fielding the Sniper XR targeting pod on the B-1. He also led the effort to train the initial B-1 combat crews to employ the pod in combat for the first time ever in B-1 history during OEF in 2008.

In 2008, Colonel Brunner was assigned to the Joint Staff as chief of the non-kinetic weapons branch in the J-8 Force Application Division where he was responsible for space, electronic warfare, and cyberspace requirements. During his time on the Joint Staff, Colonel Brunner was selected to participate on the Secretary of Defense directed Tiger Team study on long-range strike. He was also a member of the Quadrennial Defense Review long-range strike study team providing recommendations to the Secretary of Defense culminating in the decision announced on 11 January, 2011 that the Air Force was to build a new bomber.

Introduction

“Shashoujian [assassins mace] combat methods likely include what U.S. strategists refer to as A2/AD [anti-access/area-denial] strategies – strategies designed to delay the assembly of U.S. power-projection forces (to include their battle networks), to keep them beyond effective range of Chinese territory, or to defeat them once they come in range.”¹

Adversary Anti-Access/Area-Denial (A2/AD) capabilities are reducing the efficacy of U.S. land and carrier based short-range strike systems placing U.S. strategy in the Pacific and the Middle East at risk. A lack of forward basing combined with an ever increasing mobile ballistic missile threat to the Navy’s carriers will most likely ensure that U.S. forces will have to overcome enormous distances in order to provide a direct attack capability to the combatant commander. Moreover, the preponderance of U.S. long-range strike assets, the legacy bomber fleet, is old, getting harder to maintain, and is becoming increasingly unable to penetrate modern integrated air defense systems.

Measures potential adversaries are increasingly taking to mitigate the U.S. advantage in low-observable platforms and precision weapons include:

- Fielding advanced integrated air defense systems;
- Using strategic depth to move potential targets further inland;
- Hardening and/or deeply burying potential targets; and
- Increasing the mobility of key military systems, such as SAMs and missile transporter erector launchers.²

Most worrisome of the four is that many adversary A2/AD capabilities such as the DF-21D “anti-carrier” missile and anti-satellite facilities, which hold U.S. surface and space assets at risk,

¹ Andrew F. Krepinevich, *Why AirSea Battle?*, (Washington, DC: Center for Strategic and Budgetary Assessments, 2010), 15.

² Mark A. Gunzinger, “Sustaining America’s Strategic Advantage in Long-Range Strike,” PowerPoint presentation, 14 September 2010. Center for Strategic and Budgetary Assessments, Washington, DC.

are becoming increasingly mobile, presenting a very difficult targeting problem. To combat the “tyranny of distance” posed by a war in the Pacific, and in other parts of the world where forward basing is not an option, a next generation of penetrating and persistent long-range strike capabilities is vitally needed to replace the aging legacy bomber fleet. The problem will be how to build it quickly and in sufficient enough numbers so that it is not obsolete before reaching initial operational capability.

The primary question to answer is what capabilities should the United States Air Force develop for its long-range strike portfolio to overcome the tyranny of distance and geography in the Western Pacific and the Middle East to defend U.S. interests and preserve access to the global commons? A secondary, but equally important question, is how does the Air Force do this cheaply and quickly in order to build sufficient numbers of the new LRS capabilities? To answer these questions, this paper reinforces the need for a new bomber and advocates for the requirements and the technologies required to support and guide the development of the next generation of long-range strike capabilities. Discussion focuses on the capability requirements tempered with a strategy to ensure the acquisition system fields the new capability on time and on budget while meeting the combatant commander’s requirements.

The Need

Since the late 90’s, the effort to replace the legacy bomber fleet has languished and competed poorly for priority and resources within the Air Force.³ In 2006, after at least twenty studies⁴ reaffirmed the need for a follow-on bomber, the Quadrennial Defense Review directed

³ Mark A. Gunzinger, *Sustaining America’s Strategic Advantage in Long-Range Strike*, (Washington, DC: Center for Strategic and Budgetary Assessments, 2010), 2.

⁴ Adam J. Hebert, “The 2018 Bomber and Its Friends,” *Air Force Magazine* 89, no. 10 (October 2006): 24-29.

the Air Force to produce a new bomber by 2018.⁵ However, this effort was cancelled in April 2009 by Secretary of Defense Robert Gates until the need, the requirement, and the technology was better understood.⁶ To better understand the need, it is best to look at where the capability gaps exist. In *Sustaining America's Strategic Advantage in Long-Range Strike*, Mark Gunzinger highlights several shortfalls that, if not addressed in the near-term, stand to become significant problems in the out years:

- Land-based bombers, with the exception of the small B-2 force, lack the ability to penetrate and persist in high-threat air defense environments;
- US carrier air wings lack the range, persistence and survivability to support long-range strike operations in A2/AD environments, especially if enemy threats force carriers to operate beyond effective ranges for strike operations;
- Current and planned land- and sea-based strike systems, including both manned and unmanned, lack the capability and capacity to strike large target sets that are increasingly mobile, relocatable, hardened, deeply buried, and located deep in contested areas;
- Standoff weapons lack the ability to strike targets which are increasingly mobile, relocatable, time-critical, hardened or deeply buried; and
- Airborne electronic attack platforms lack the range and survivability needed to support long-range strike operations in contested airspace.⁷

The B-1 and B-52 are excellent platforms for current irregular conflicts, but will be challenged to operate within A2/AD environments where the air defense network is more robust. Even the B-2

⁵ *Quadrennial Defense Review Report*, (Washington, DC: Department of Defense, February 2006), 46.

⁶ Robert M. Gates, secretary of defense, Department of Defense (address, Defense Budget Recommendation Statement, Arlington, VA, 6 April 2009).

⁷ Mark A. Gunzinger, *Sustaining America's Strategic Advantage in Long-Range Strike*, xi-xii.

is reaching its zenith with regard to penetrating an advanced air defense network.⁸ Realistically, future air defense network capability increases may relegate all three platforms to a standoff role until the threat can be suppressed with standoff weapons or other means.

The “tyranny of distance” is a significant limitation facing U.S. forces in the future as potential adversaries take advantage of the “range gap” created by an overemphasis on short-range platforms. The *Technology Horizons* report succinctly summarizes the conundrum the U.S. faces:

The threats posed to U.S. air bases in the Pacific by ballistic missiles create significant technology challenges for maintaining air power projection in this region. The long ranges required for operations in the Pacific entail substantial tanking requirements that put a premium on long-range strike capabilities and fuel-efficient propulsion systems. The air-sea battle concept based on synchronized Air Force and Navy operations against a potential near peer competitor in this region may also require significant new capabilities.⁹

From a capabilities perspective, a long-range, penetrating, persistent strike aircraft provides the combatant commander a very responsive, tailorable capability due to the ability to carry a wide range of weapons. Armed with both direct-attack, self-defense, and standoff weapons, the next-generation bomber provides a robust, autonomous strike capability. It must be survivable and its weapons bay capacity must be large enough to enable striking a spectrum of multiple targets per mission. The cost per target must remain low. Furthermore, integrating advanced intelligence, surveillance, and reconnaissance capabilities into the platform increase the value of the next-generation bomber even more. If designed properly, the next-generation bomber stands to become the utility player for the Air Force capable of performing a wide range of missions in a wide range of environments.

⁸ Ibid., 56.

⁹ USAF Chief Scientists (AF/ST), *Technology Horizons*, Volume 1, A vision for Air Force Science and Technology During 2010-2030, report, 15 May 2010.

The Requirements

“Finally, a major area of investment for the Air Force will be a new long-range, nuclear-capable penetrating bomber. This aircraft, which will have the option of being remotely piloted, will be designed and developed using proven technologies, an approach that should make it possible to deliver this capability on schedule and in quantity.”

“It is important that we begin this project now to ensure that a new bomber can be ready before the current aging fleet goes out of service. The follow-on bomber represents a key component of a joint portfolio of conventional deep-strike capabilities, an area that should be a high priority for future defense investment, given the anti-access challenges our military faces.”

-- Secretary of Defense, Defense Reform Briefing, 11 January 2011.¹⁰

Secretary Gates’ comments in January acknowledged the need for and set the baseline requirements for a new bomber. Long-range, nuclear-capable, optionally manned, using existing technologies; these are the key concepts specified by the Secretary which must frame the requirements debate. Furthermore, the Secretary directed the Air Force to begin this project now in order to prevent a gap between achieving operational capability and the retirement of the aging legacy fleet. However, even if this program is included as a new start in the FY12 budget, it will be at least 2025 before a new bomber reaches initial operational capability.¹¹ Another element addressed was that the new bomber will be a key component of the joint portfolio of long-range strike capabilities. Tackling the A2/AD environment requires a supporting cast of characters to ensure success in a dense threat environment; especially while sniffing out mobile targets. The new bomber will be but one sibling in a family of systems and sensors collaborating and cooperating to overcome the challenges of operating in an information-denied environment.¹²

¹⁰ Robert M. Gates, secretary of defense, Department of Defense (address, Department of Defense News Briefing, Arlington, VA, 6 January 2011).

¹¹ John A. Tirpak, “Air Force Eyes 80 to 100 New Bombers,” *Air Force Magazine – Daily Report*, 15 February 2011, <http://www.airforce-magazine.com/Pages/default.aspx>, accessed 15 February 2011.

¹² Stephen J. Hadley and William J. Perry, *The QDR in Perspective: Meeting America’s National Security Needs in the 21st Century*, independent panel report to Congress (Washington DC: United States Institute of Peace), 60.

Family of Systems

It is important to understand that long-range strike must be a portfolio of capabilities not necessarily hosted on a single platform. In addition to incorporating traditional measures such as passive low-observable technologies, the family of systems concept provides enhanced survivability “by committee.” At the Air Force Association convention in September 2010, General Schwartz hinted at what lies ahead:

Fundamental to this is a viable Long-Range Strike capability—an Air Force core contribution that combines multiple systems to provide the Nation with the capability to overcome area-denial measures, penetrate contested airspace and networks, and assure freedom of action to deliver air, space, and cyber power effects. Currently, the Air Force and Office of the Secretary of Defense are very carefully developing our concept of a family of systems that will continue to provide this capability, and ensure its maximum flexibility and longevity through a careful balance between simpler and more complex capabilities and platforms, including, we suggest, a penetrating bomber.¹³

The family of systems concept is essential to waging a complex air campaign in an A2/AD environment. Advanced unmanned systems conducting intelligence, surveillance, and reconnaissance (ISR) and/or airborne electronic attack, cooperating and collaborating amongst each other, will supplement the onboard active defensive capabilities of the new bomber, and other platforms, to enhance survival.

Major Combat Operations vs. Irregular Warfare

A penetrating, persistent, direct attack capability able to autonomously find, fix, track, target, engage, and assess mobile and fixed targets is required regardless of whether the U.S. is engaged in major combat operations in an A2/AD environment or an irregular warfare scenario in a permissive environment. Integrating the capabilities to conduct a close air support mission

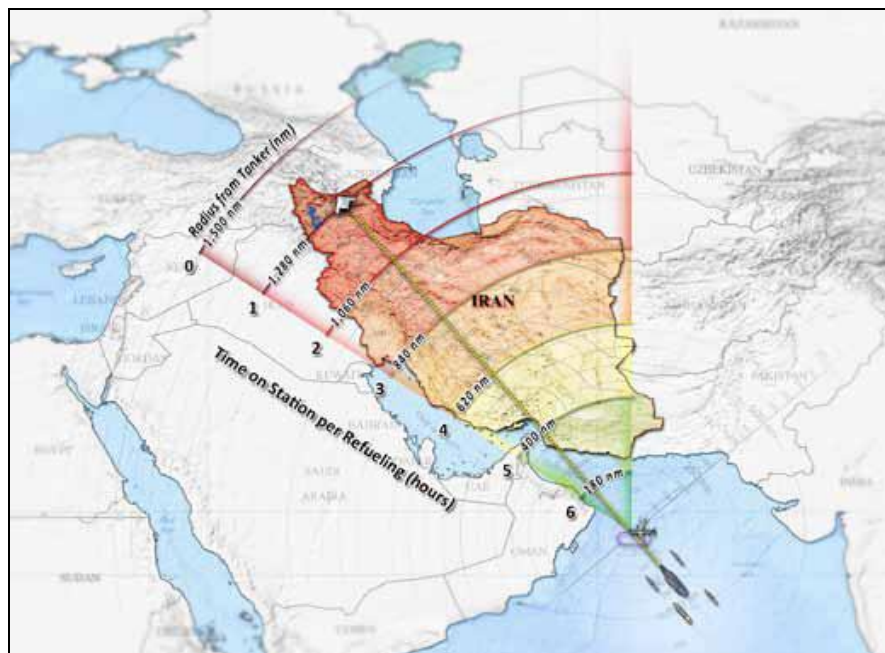
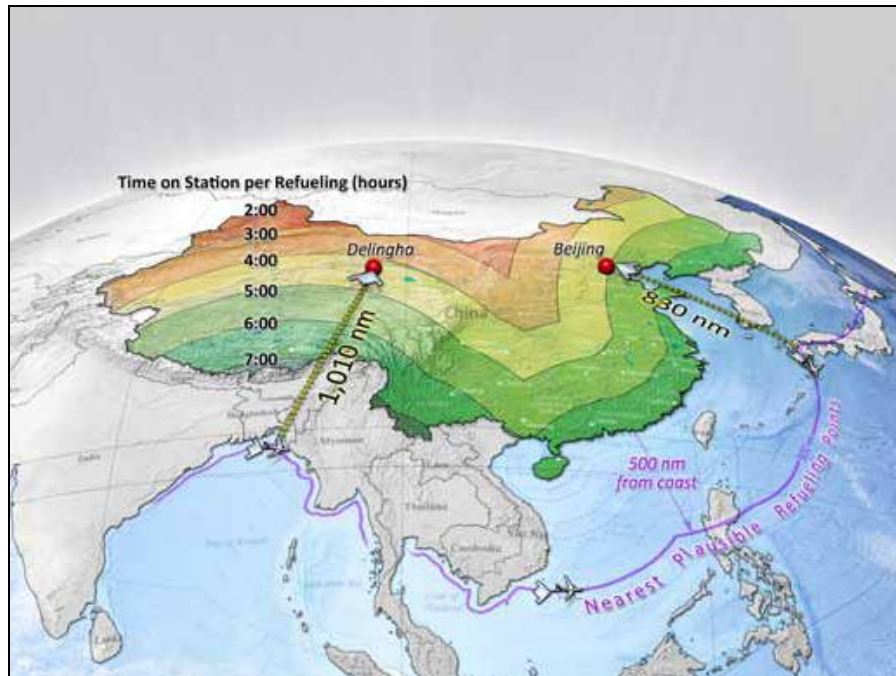
¹³ Gen Norton A. Schwartz, chief of staff, US Air Force (address, Air Force Association Convention, Washington, DC, 14 September 2010).

in an urban environment is just as important as integrating those required to conduct a deep strike against a fixed target. To overcome the A2/AD challenge, a new bomber must be capable of achieving at least 2,500NM combat radius to reach the majority of targets of interest (Figure 1). In addition to being highly survivable to penetrate future A2/AD environments, it must also persist to hunt mobile targets (Figure 2 & 3).



Figure 1. Representative ranges from Diego Garcia and Guam.¹⁴

¹⁴ Mark A. Gunzinger, *Sustaining America's Strategic Advantage in Long-Range Strike*, Chap. 1, Figure 1.



¹⁵ Mark A. Gunzinger, *Sustaining America's Strategic Advantage in Long-Range Strike*, Chap. 2, Figure 2.

¹⁶ Ibid., Chap. 2, Figure 3.

Due to inherent limitations, a standoff weapons only approach will not get the job done. Countries with strategic depth, such as China, have inherent geographic sanctuaries where high-value targets are located leaving some targets simply out of range of short-range strike aircraft and stand-off weapons launched from outside an integrated air defense system. Current standoff weapons also lack a datalink to react to mobile targets in addition to a suitable warhead to prosecute hardened and deeply buried targets. Realistically, without a datalink, the time-of-flight of current stand-off weapons is too long to strike mobile or relocatable targets at medium to long ranges. This combination of limitations drives the requirement to penetrate an integrated air defense system (capability must be survivable) and persist to find, fix, track, target, engage, and assess mobile targets (e.g., DF-21) or deep targets (e.g., laser facilities) holding U.S. space and surface assets at risk. Additionally, some deep, hardened targets may simply be out of range for a standoff missile and will require a direct attack with a robust penetrating capability (e.g., GBU-28, Massive Ordnance Penetrator-like capability, etc).

Irregular Warfare

In as much as a new penetrating bomber is needed for future major combat operations in A2/AD environments, it must also be capable of being a deciding factor in the irregular warfare fight. It is too significant of an investment not to be a jack of all trades. Within this environment, technology priorities must be given to developing and integrating advanced electro-optical / infrared sensors onto the aircraft. Low-observable signatures and advanced electronically scanned array radars remain vital components in the permissive to semi-permissive environment which characterize the irregular warfare arena. However, as the incredible demand for persistent intelligence, surveillance, and reconnaissance in Afghanistan and Iraq has demonstrated, electro-optical / infrared sensors are extremely valuable to ensure positive target

identification, collateral damage estimation, convoy support, and general deconfliction with friendly forces. Technology such as ROVER, an air-to-ground datalink streaming targeting pod video to a laptop on the ground, has become invaluable in the air-ground battle, especially in the close air support mission where the U.S. repertoire of precision weapons are routinely dropped in close proximity to friendly troops and civilian structures. An advanced, electronically scanned array radar with very high resolution is an excellent targeting tool. However, even with the best automatic target recognition algorithms, radar cannot replace the ability to put actual eyes on the target. A targeting pod, for example, provides the ability to “stare” in real time, for long periods of time. Radar can only provide a snapshot in time. Nor can radar replace the interaction between soldier and airman made possible by streaming video. A ROVER-like capability significantly decreases the time required to “talk” an aircrew on to the target resulting in achieving the desired effect sooner.

An electro-optical / infrared sensor is also a “must have” sensor for major combat operations. As stated previously, mobile targets holding U.S. surface and space assets at risk are a serious concern to the combatant commander. Hunting and killing mobile targets is a daunting challenge which requires an onboard, autonomous positive target identification with an electro-optical / infrared sensor prior to committing a weapon to the target. Moreover, due to the likely presence of datalink jamming and the proliferation of camouflage, concealment, and deception techniques, an onboard electro-optical / infrared suite is an even more absolute requirement. An advanced electronically scanned array radar with automatic target recognition, potentially cued from an offboard source, will most likely be used to provide initial location fixing and class determination. However, in most cases, final weapon cueing will come from the electro-optical / infrared sensor to ensure positive target identification.

The next-generation bomber will also provide persistent, non-traditional ISR. Due to inherent range and loiter, a bomber is an excellent ISR platform. In 2008, for the first time ever, B-1s deployed to the AOR with the Sniper XR targeting pod. Adding an EO/IR sensor to the B-1 has increased its versatility tremendously and B-1s are now conducting traditional fighter roles such as armed overwatch missions in addition to fulfilling ISR mission requests.

Acquisition Strategy¹⁷

“Long-Range Strike will be an evolutionary approach to balance existing, evolving, and new capabilities, not a vast and prohibitively expensive multi-platform acquisition program.”

-- CSAF Speech to September 2010 Air Force Association Convention.¹⁸

As Gen Schwartz implies above, the U.S. can no longer afford to develop smaller numbers of exquisite, high-end, high-cost capabilities. If the acquisition community cannot control the cost of future LRS capabilities in order to procure a reasonable fighting force, the resulting capacity problem created by fielding a small fleet will inevitably reduce the ability of the U.S. to seize the initiative and determine the tempo of a conflict with a near peer adversary. Quantity, therefore, must be smartly balanced against quality. Numbers do matter especially in light of the growing A2/AD problem which is becoming a serious concern with regard to prosecuting a major combat operation. This is no more apparent than in the Pacific, where significant hurdles must be leapt due to lack of forward basing and a dependence on naval forces to provide the preponderance of combat capabilities.

¹⁷ This section was developed with the assistance of Col (Ret.) P.J. Clark, former commander of the B-1 Aeronautical Systems Group at Wright-Patterson AFB. He provided advice in a series of e-mail exchanges with regard to the overarching premise of resisting no new inventions on schedule – i.e., no revolutionary technology.

¹⁸ Gen Norton A. Schwartz, chief of staff, US Air Force (address, Air Force Association Convention, Washington, DC, 14 September 2010).

During World War II, it is a unanimously held belief that the Germans held a qualitative edge over the Allies when it came to tank technology. The Tiger tank and 88mm gun was superior in every respect save one; it was outnumbered significantly.¹⁹ At some point, losing the quantitative edge can potentially cede the ability to seize the initiative and dictate the tempo to the side that has the most. The Allies were able to use vastly superior numbers of an inferior technology – the Sherman tank – to overcome the smaller German force of superior technology. It is only a matter of time before a near-peer competitor such as China out produces the United States’ military machine. Moreover, China’s emphasis on asymmetric capabilities – e.g. electronic warfare – also exacerbates the problem by reducing the United States’ technological advantage.

Resist “Invention on Schedule”

“We’re not going to be as ambitious as we perhaps were at one time. That I think will make it a little easier for us to manage and less challenging for industry to keep their promise.”

-- CSAF Speech to 9 Feb 2010 National Defense Industrial Association’s Special Operations/Low Intensity Conflict Symposium.²⁰

In order to produce a new bomber quickly, and in sufficient numbers, there must be no new inventions. This must be the number one rule that is religiously adhered to or costs will soar. Inside the defense industry today, there are well-understood, *in production*, or *already produced* technologies that can be used on this aircraft. For example, the U.S. cannot afford to pursue high-end low-observable technologies. Extremely low-observable signatures may be desirable, but the cost is too high to pay. B-2, F-22, and F-35 signature reduction technologies must be the baseline. For the smaller number of targets where a high-end signature is required,

¹⁹ Dr. Mark Conversino, “Fighting (and Winning) This War While Preparing for the Next,” PowerPoint presentation to Air War College students, 4 January 2011, Air War College, Maxwell AFB, AL.

²⁰ Amy McCullough, “Promises Aren’t Made to be Broken,” *Air Force Magazine – Daily Report*, 10 February 2011, <http://www.airforce-magazine.com/Pages/default.aspx>, accessed 10 February 2011.

develop an extremely low-observable or hypersonic standoff weapon where speed negates the need for a low signature. Other areas to pursue are using a currently flying engine, adapting F-35 radar functionality into a B-2 advanced electronically scanned array, modifying F-35 and/or F-22 mission/sensor fusion software, adapting the F-35 electro-optical targeting system, and other subsystems such as fuel, hydraulics, ejection seats, etc. from proven and fielded systems. To enable the optionally manned capability, current remotely piloted aircraft control systems must be used to ensure commonality and compatibility with *current* ground control stations and for training. There absolutely cannot be a new ground control architecture required to support the optionally manned option. The key concept to remember is that if this program requires "invention on schedule," like the F-22 development program, it is simply being set up to fail as the first invention which fails to meet schedule, no matter how big or small, inevitably extends development and raises costs. Which history has shown will reduce the most critical attribute: fleet size.

Hand in hand with deeming no new inventions is managing requirements creep. Once the requirements are set, a watchdog must be appointed to prevent the introduction of new requirements. The VH-71 presidential helicopter and B-52 stand-off jammer programs are excellent examples of requirements creep causing costs to skyrocket leading to eventual termination due to unaffordability.²¹ Seeking the 100%, gold-plated solution must not, and cannot be allowed. The new paradigm must be building to the 75% solution with the capability to respond to "evolving conditions and needs" via block upgrades.²² As recently stated by Paul Kaminski, Chairman of the Defense Science Board, an important notion underlying the block

²¹ John A. Tirpak, "Where Next with Electronic Attack?" *Air Force Magazine* 89, no. 10 (October 2006): 30-34.

²² *Enhancing Adaptability of U.S. Military Force*, Defense Science Board Report, Washington DC: Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, January 2011. 71.

upgrade mentality is that, “you want to be careful not to overreach with the first block.”²³ But it is also important that the opposite doesn’t happen. To build a “growth ready” platform, it is critical for the first block to have an open architecture, an adequate number of apertures for offensive and defensive sensors/capabilities, and a re-configurable weapons bay to adapt to changing mission needs. Growth space must be built into the first block in order to keep costs lower for subsequent blocks. Future additions of evolutionary technologies, be it weapons, electronic warfare systems, sensors, etc. will be much easier and cheaper if the aircraft has good bones. This requires an up-front shift in mentality from pursuing revolutionary, stovepipe capabilities to limiting the requirements to evolutionary capabilities which are more easily achievable in the near-term. In the end, chasing revolutionary capabilities draws out development, testing, and fielding significantly.

The F-22 was a revolutionary endeavor that took 20+ years to realize as most of the technology had not been invented when the process started. And yet, we’re still not done evolving that airplane and the “do everything for everybody” F-35 appears to be headed down the same path potentially resulting in a reduced inventory as airframes are traded to pay for increases in cost. Bottomline: “invention on schedule” is fraught with peril. The requirement must be limited to evolution, don’t allow revolution, fight and defeat requirements creep, be decisive in determining the requirements, keep the funding stable so as to not stretch out the development (which will induce requirements creep), and then execute and prepare for the next evolution.

As this aircraft will undoubtedly replace the legacy bomber fleet, another major problem to address is building it in sufficient quantities. Procuring a one hundred aircraft fleet at six

²³ Dave Majumdar, “USAF Scaled Back Vision for New Bomber,” DefenseNews.com, 9 February 2011, <http://defensenews.com/story.php?i=5665221&c=AIR&s=ALL>, accessed 10 February 2011.

airframes per year ensures that the last aircraft rolling out of the production facility will be multiple block upgrades behind. Production rates comparable to the F-35 program must be achieved to keep costs down and to ensure that the new bomber is delivered in a timely manner so as to replace the legacy bomber fleet at a rate that doesn't create a capability gap. This is an important consideration as even though the B-1 and B-52 are programmed to be around until 2040, a catastrophic airframe failure due to aging, such as that experienced by the F-15 fleet in 2007, could cause a significant loss in long-range combat capability for a significant amount of time.

Nuclear Requirements

A dual-capable aircraft must have special requirements dealt with up front. Per Secretary Gates' direction, the new bomber will be nuclear capable. With this capability comes a whole host of special requirements, the most pressing and most costly being electromagnetic pulse (EMP) hardening. The Chief of Staff of the Air Force, General Schwartz, has made statements in the press stating that the first blocks would not be nuclear capable but would have the wiring architecture to enable EMP hardening in later blocks.²⁴ This approach may prove more costly than anticipated as EMP hardening is extremely expensive. Hardening the aircraft in the first block should save sizable costs in the long run versus trying to do it in the future as hardening is more than just shielding wiring.

Technology

In addition to "borrowing" technology from aircraft in development and fielded systems, there are technology development programs underway that may add capabilities to the initial and

²⁴ John A. Tirpak, "The Bomber Question," *Air Force Magazine* 93, no. 12 (December 2010): 22-27.

subsequent blocks as the need arises. This paper will discuss a few of the key efforts; primarily in survivability enhancements, hypersonic stand-off weapons, and autonomous systems.

Survivability

Future improvements in signature reduction will come in smaller increments at an ever increasing cost as the methods for gaining a couple of decibels of reduction in radar cross section become increasingly exquisite. Remember: “no invention on schedule.” It is for this reason that the low-observable technologies used on the new bomber should be based on the current gold standard – i.e. B-2, F-22, and F-35. Moreover, as much as the U.S. relies on stealth to confuse air defense networks, counter- low observable efforts abound and stealth technology may soon approach its zenith. It is quite possible that in the near future, the key to overcoming the stealth monopoly may be right around the corner – much to our detriment. If the new bomber is going to penetrate, persist, and survive in an A2/AD environment, speed should be a consideration. However, regardless of how fast it flies, the new bomber will require a combination of signature reduction efforts *and* advanced electronic warfare systems to survive.

Bring Back the Electronic Warfare Officer

Relying on low-observable technology as a panacea has drastically reduced the importance of electronic warfare in the Air Force culture whereas potential adversaries have capitalized on the asymmetric advantage electronic warfare affords. Even though the new bomber will most likely be low-observable, it will be cost prohibitive to pursue extremely low-observable options necessitating the need to be outfitted with advanced electronic warfare capabilities to enhance survival. Rather non-complex in nature, the rapidly proliferating digital radio frequency memory radar jammer threat is but one of many electromagnetic spectrum

challenges to U.S. qualitative superiority. A robust active electronic attack suite must be incorporated and supplemented with on-board defenses (i.e., AMRAAM or a future dual-role missile) to accommodate operations beyond family of system coverage such as when employed in a nuclear role. Even though technology exists to reduce a platform's signature in the RF portion of the spectrum, advances in infrared tracking systems should cause concern.

Making an Aircraft Disappear

Stealth is a multi-spectral problem set. Any low-observable platform is susceptible to detection and tracking via infrared sensors. This is a problem that is yet to be resolved as the core issue becomes how to cool the skin of an aircraft and its engines to blend into the background IR environment. This is an incredibly daunting task considering the added weight and cost a "refrigerant" system (e.g., running cooling loops through the skin of an aircraft) would add and the potential payload tradeoffs to carry it. Using metamaterials to reduce or eliminate an objects infrared or optical signature may provide an answer to this problem. However, much work is left to be done in this area and fielding any technology to make an aircraft "disappear" is well into the future. A significant potential benefit enabled by a technological revolution in this area, though, would be the ability to fly during the day; doubling the number of sorties and weapons available for prosecuting a conflict. Looking beyond radar, infrared and optical signature reduction efforts, speed is another area to address with regard to survivability and lethality.

Hypersonic Stand-off Weapons

Responsiveness must be a key attribute of any future penetrating, persistent strike capabilities. Speed is critical to solving the mobile target (esp. DF-21) problem as it enables

attacking emerging targets before they move and become no longer vulnerable. Speed also shrinks the advantage of strategic depth and mobility by compressing the temporal aspect of the killchain. Speed also provides energy to avoid or defeat a threat. However, one downside of a supersonic platform is increased airframe and engine infrared signatures. Therefore, speed is an important attribute to weigh the benefits of in terms of stealth (probability of detection), responsiveness, and survivability.

Hypersonic technology is increasingly becoming a realistic path to increase responsiveness.²⁵ Hypersonic weapons can provide a robust option to render an advanced air defense network ineffective. A Mach 6+ weapon is a very difficult target to engage. Surface-to-air missile kinematics simply cannot match that of a hypersonic weapon enabling more targets to be held at risk with fewer weapons, particularly when attacking a missile site directly. It will take significantly fewer fast, somewhat low-observable weapons to strike air defense targets versus a larger number of slow, very low-observable weapons which rely on causing confusion in hopes that one or two will make it through the defenses.

There are important considerations to take into account when developing a hypersonic stand-off weapon. The first is size – a hypersonic weapon is going to be large. For example, the first-generation X-51 hypersonic engine demonstrator is not a small system. In addition to weapons bay size, how deep one wants to hold targets at risk will also determine how large a hypersonic cruise missile will be. There will be a breakpoint whereupon weapon weight and size restricts the number of missiles that can be carried. The larger the weapon becomes, the less a platform can carry reducing the amount of targets destroyed. Second, a hypersonic weapon may

²⁵ Glen Liston, "Hypersonic Long Range Strike Technology Applications," PowerPoint presentation to Air War College Center for Strategy and Technology Students, 22 September 2010. Air Force Research Laboratory, Wright Patterson AFB, OH.

not be the best option for hardened and deeply buried targets depending on the size of the warhead; if it has a warhead at all. Kinetic effects may not be enough to go deep. Third, any hypersonic weapon has the potential to be expensive resulting in a small, niche capability. Fourth, material development must keep pace with engine development. Finally, hypersonic weapons will be inherently inflexible due to short times-of-flight and limited ability to maneuver due to high speeds. With these considerations understood and mitigated (particularly size), the efficacy of a hypersonic weapon appears to be solid, especially against a surface-to-air missile system and mobile targets. The raging debate regarding using the new bomber in an optionally manned configuration is another matter.

Autonomous Systems

No other aspect of discussion on the new bomber raises more ire than the debate between manned or unmanned options. Unmanned is logical for persistent ISR. It is simply not logical for a strike platform, especially a nuclear-capable one. Killing targets requires human interaction for a variety of reasons described in the following paragraphs. Moreover, the argument can be made that a remotely piloted aircraft requires more manning. Instead of a single crew flying a 24 hour sortie, a single MQ-9 sortie uses 10 pilots in addition to personnel manning ground control stations (174 total personnel for a single 24 hour UAS sortie).²⁶ With the case of an optionally manned bomber, much discussion lies ahead with regard to aircrew disposition; i.e., will aircrew perform both the manned and unmanned mission or will they only be trained to perform one? Training is also an issue as the cost of a new bomber will most likely require a manned presence

²⁶ Bruce Rolfsen, "Unmanned a Misnomer When it Comes to UAVs," *Air Force Times*, 11 June 2010, http://www.airforcetimes.com/news/2010/06/airforce_uav_personnel_061110w/, accessed 15 October 2010.

in the cockpit for unmanned missions to ensure safe recovery in case of lost link (this isn't a Reaper that can be easily replaced).

Development of autonomous systems is becoming a cornerstone capability for the future Air Force. Much work is being done in this area, and some postulate that significant advances will occur in the next decade, but a lot more needs to be done before a truly autonomous system capable of making decisions on its own is fielded: "And, while unmanned platforms likely better serve this required persistence from a physiological perspective, current technology does not allow for the type of fully autonomous and dynamic systems that are required in an opposed and networked environment."²⁷ Moreover, datalink vulnerability is the greatest cause of concern "I am increasingly concerned as a combatant commander and as the guy who's responsible for this a significant portion of this link regarding its vulnerability."²⁸

The efficacy of employing unmanned aircraft in purely autonomous operations is debatable. Cooperative autonomous operations with a man in the loop, however, are more likely due to the net synergistic effect of distributed sensors across many platforms, manned and unmanned, collaborating as one. There are benefits of doing so; 1) enabling a task that cannot be accomplished by a single unmanned system, 2) reducing timelines, and 3) combine heterogeneous sensing capabilities into greater overall capability.²⁹ This capability should be at the core of the family of systems architecture.

²⁷ Gen Norton A. Schwartz, chief of staff, US Air Force (address, Air, Space, and Cyberspace Power in the 21st Century Conference, Washington, DC, 20 January 2010).

²⁸ Scott Fontaine, "USAFE Chief: Don't Rely on UAVs," *Air Force Times*, 30 July 2010, http://www.airforcetimes.com/news/2010/07/airforce_UAVs_073010/, accessed 2 August 2010.

²⁹ Caroline King, "Cooperative Control Overview for AWC/ACSC," PowerPoint presentation to Air War College Center for Strategy and Technology Students, 22 September 2010. Air Force Research Laboratory, Wright Patterson AFB, OH.

In as much as it is desirable to remove the human from the cockpit to increase endurance, there are significant drawbacks of doing so. First of all, war is a human endeavour. There are serious moral and ethical issues associated with allowing a machine kill a human being without human input. This is a recognized area of concern with regard to international laws of warfare and is problematic in many regards.³⁰ Assuming that automatic target recognition will be 100% “trustable” is a stretch. Therefore, trusting a machine to identify and kill a target based on technology which will never be able to *fully* overcome the natural laws of physics is a serious issue to address. Without 100% certainty/confidence, it is doubtful that rules of engagement will allow its autonomous use. Today’s interconnected world is too casualty averse and expects a war to be fought humanely and cleanly. There are simply too many known unknowns that only a human will be able to sense and react to.

The inherent potential for blue-on-blue fratricide becomes another overriding consideration when deciding whether a system can truly go autonomous or not. The problem becomes ensuring whether automatic target recognition algorithms can distinguish between a T-72 and an M-1 in a close battle. Even if the most advanced automatic recognition software has a 1% chance a misidentification might occur, can one fully trust an autonomous unmanned system to provide close air support in a troops in contact situation? I tend to think the answer will be “no” even in the 30’s. There is simply too much risk involved when considering the vulnerabilities to an autonomous system. Moreover, how would an autonomous system do collateral damage estimation?

Collateral damage estimation is not a science. It is applied science and operational art – i.e., scientific principles tempered with a healthy dose of judgment and experience. There are

³⁰ Caroline King, “Cooperative Control Overview for AWC/ACSC.”

too many ambiguities that cannot yet be accounted for with millions of lines of code: “Even if equipped with current automatic target recognition systems, the sheer computational power needed by a UAS to autonomously determine if a weapons release would result in unacceptable collateral damage goes well beyond the state of the art in artificial intelligence.”³¹ Artificial intelligence cannot yet substitute for a human-in-the-loop with so much on the line.

Conclusion

In the end, the Department of Defense simply cannot afford to mismanage itself into a twenty aircraft fleet again like the B-2. At two billion dollars per copy, the loss of a single B-2 leaves a large hole in capability and options: “...by accident, or in combat – results in a loss of a significant portion of the fleet, a national disaster akin to the sinking of a capital ship.”³² Even though it is a very capable platform, there simply are not enough of them to sustain a high sortie tempo to have a sustained impact in a major combat operation. Moreover, upgrades come with an enormous price tag due to small quantities. Secretary of the Air Force Donley’s comments at the 2010 Air Force Association convention conveys the Air Force’ way forward on long-range strike: “But we are also cautious. Cautious not to repeat the painful experience of previous Air Force bomber programs: narrowly focused capabilities, high risk technologies, and high costs contributing to affordability problems, leading to program cancellations, or low inventories.”³³

The Air Force has a long way to go to field a new bomber. Decisions remain to be made with regard to overarching capability requirements. However, since the Secretary of Defense directed the Air Force to use existing technologies, the most challenging aspect will not be

³¹ Mark A. Gunzinger, *Sustaining America’s Strategic Advantage in Long-Range Strike*, 43.

³² Robert M. Gates, secretary of defense, Department of Defense (address, Air Force Association Convention, National Harbor, MD, 16 September 2009).

³³ Michael B. Donley, secretary of the air force, US Air Force (address, Air Force Association Convention, Washington, DC, 13 September 2010).

technology development itself as there should be very little inventing; it will be maintaining cost and schedule. In order to produce a new bomber quickly, and in sufficient numbers, there must be no new inventions. This must be the number one rule that is religiously adhered to or costs will soar – with one caveat. Hypersonic weapons and electronic warfare appear to be very good complementary investments in the long-range strike family of systems at this time. Completely autonomous unmanned operations, however, need to be addressed in a later block until automatic target recognition technology matures and datalink vulnerability is reduced.

Industry needs to be a responsible partner as funding gets tighter and tighter. At a recent industry conference, when an audience member asked General Schwartz what industry could do to help, he replied: “Deliver what you promise. Period. Dot. Don’t blow smoke up my ass. There is no time for it. There is no money for it. There is no patience for it.”³⁴ We live in a time of acute fiscal austerity where all parties must do their part to ensure the defense of the nation is assured. Inside the defense industry today, there are well-understood, *in production*, or *already produced* technologies that can be used on this aircraft. Seeking the 100%, gold-plated solution must not, and cannot be allowed. The new paradigm must be building to the 75% solution with the capability to respond to “evolving conditions and needs” via block upgrades. Bottomline: “invention on schedule” is fraught with peril. The requirement must be limited to evolution, don’t allow revolution (i.e., beware becoming enamored with technology promises by industry), fight and defeat requirements creep, be decisive in determining the requirements, keep the funding stable so as to not stretch out the development (which will induce requirements creep), and then execute and prepare for the next evolution. Period. Dot.

³⁴ Amy McCullough, “Promises Aren’t Made to be Broken,” *Air Force Magazine – Daily Report*, 10 February 2011, <http://www.airforce-magazine.com/Pages/default.aspx>, accessed 10 February 2011.

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